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SENSING OF METEOROLOGICAL VARIABLES
BY LASER PROBE TECHNIQUES

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SUMMARY OF RESEARCH

Some work is being carried out as a cooperative effort among Giorgio Fiocco at the European Space Research Institute (ESRIN), Frascati, Italy, and Gerald W. Grams and J. B. DeWolf at the Research Laboratory of Electronics, M.I.T. It is a continuation of work previously supported, in part, by NASA Grant NGR 22-009-131.

The following studies are being conducted.

1. G. Fiocco and G. W. Grams are working on a study of the meridional circulation of dust in the upper atmosphere. Using the wind velocities obtained through the model of R. J. Murgatroyd and F. Singleton,¹ we are studying the seasonal variation of the meridional distribution of dust in the upper atmosphere.

2. Optical Radar data obtained during 1964 and 1965 are being reduced in order to obtain an idea of the seasonal variability of mesospheric dust content. Preliminary results point to a seasonal variation that can be interpreted through the use of the theoretical model just mentioned.

3. Studies are being conducted on the spectrum of coherent light scattered from turbulence. This research is now being carried out, for the most part, by J. B. DeWolf in doctoral thesis research. A brief report follows.

Spectrum of Coherent Light Scattered from a Turbulent Jet

It has been thought that information about turbulence and aerosol diffusion might be obtained by studying the spectrum of the light scattered by the aerosols with the use of an optical homodyne spectrometer.² A preliminary study using a steam jet showed, however, that the homodyne spectrum was masked by intensity fluctuations caused by intermittent behavior and density fluctuations in the jet. Fluctuation spectra of this sort have been observed by Becker, Hottel, and Williams.³ In order to clarify the situation and to see if a homodyne spectrum could be obtained from a turbulent fluid, a study was begun of the spectrum of coherent

light scattered from a water jet marked by uniform spherical particles. This portion of the report will summarize what has been learned thus far, by using the turbulent water jet.

The homodyne spectrum gives information about the density correlation function of the particles.⁴ It is observed by measuring with a wave analyzer the low-frequency spectrum of the current from a photomultiplier tube which is illuminated by the scattered light. In order to interpret the observed spectrum simply in terms of a density correlation function, the following conditions should be satisfied.

a. The fluctuations in scattered light intensity caused by a change in the total number of scattering particles within the volume should be small. In order to determine whether or not this is the case, it is useful to measure the photocurrent spectrum when incoherent light is used as the source. The homodyne spectrum is only observable with a laser source.

b. The turbulence should be statistically stationary over the time of the measurement.

c. The volume that is observed should be large enough so that the broadening caused by the finite lifetime of the scattering from a particle moving through the volume can be neglected. If the mean velocity of the particles is v , and the width of the homodyne spectrum that is to be observed is Δf , then the size of the scattering volume L should satisfy

$$L \gg \frac{v}{\Delta f} .$$

This may be the major source of broadening in experiments in which the mean velocity of the fluid is large or the scattering volume small.

d. Ideally, the volume that is observed should be small enough so that the mean velocity of the fluid is essentially constant within the volume. This is desirable so that the density correlation function will be more or less homogeneous over the scattering volume.

Some measurements of the spectrum of light scattered by particles suspended in a submerged water jet have been made in such a way that these conditions are reasonably well satisfied. The jet emerges from a nozzle, 1 mm in diameter, into a glass-walled circular duct, 5.33 cm

in diameter. Both the water emerging from the jet and the water in the duct are marked with uniform latex spherical particles having a diameter of $910 \text{ \AA} \pm 58 \text{ \AA}$. The jet can be moved relative to the laser beam and the photomultiplier in such a way that the position of the scattering volume may be precisely located with respect to the center line of the jet and the nozzle. The flow rate is measured with a calibrated flowmeter. The homodyne spectrometer is similar to the one described by Dubin, Lunacek, and Benedek.² The photocathode is at right angles to the laser beam.

A detailed analysis of the data has not yet been completed, but the following general picture emerges.

First, when the jet is turned off the particles undergo Brownian motion. The density correlation function and the spectrum of the light observed in this case are well understood. The line shape is Lorentzian and has a width that is proportional to the diffusion coefficient. Since the diffusion coefficient for the uniform spherical particles can be calculated from the Stokes-Einstein relation, the width of the spectrum can be calculated and compared with experiment. Figure 1 shows the spectrum of the light observed when the jet is turned off. The solid curve is a Lorentzian having a width of 0.79 kHz, which agrees well with the calculated value.

Second, when the jet is turned on, the spectrum of the light scattered from the jet region is observed to broaden. It is inferred that the broadening of the spectrum is caused by an increase in the effective diffusion coefficient because of the turbulence. The observed spectrum maintains a Lorentzian shape, at least initially, as the jet velocity increases. Figure 2 shows the spectrum of the light observed 40 nozzle diameters downstream from the nozzle on the axis of the jet when the nozzle velocity is approximately 525 cm/sec. The curve has a width of approximately 5.6 kHz.

Third, as the scattering volume is moved radially, the width of the spectrum decreases until the minimum width (caused by the equilibrium Brownian motion) is reached. This behavior has been examined as a function of the distance from the nozzle and it is possible to observe in

Fig. 1. Spectrum of light scattered from spheres of 910 \AA diameter undergoing Brownian motion in a water solution. Solid curve is Lorentzian with 674 Hz width.

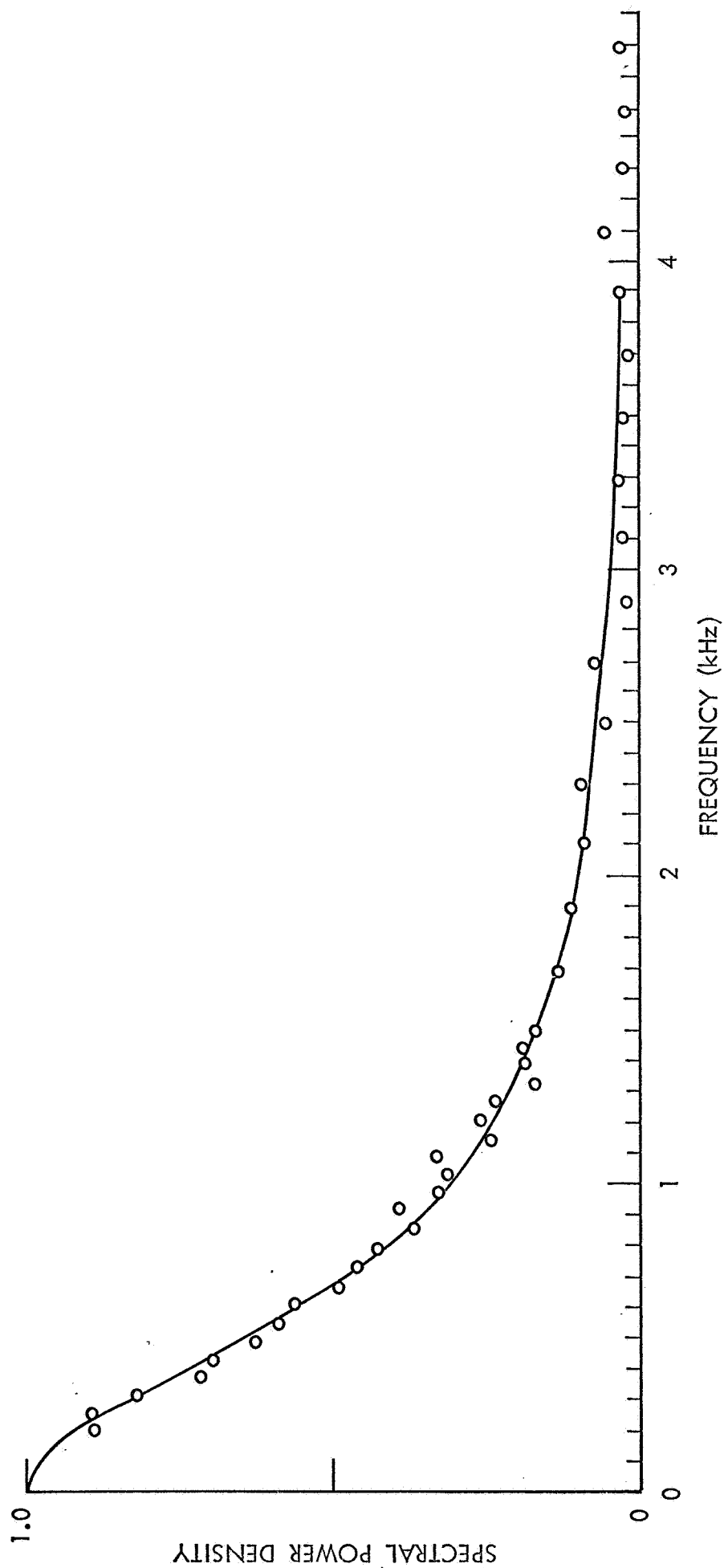
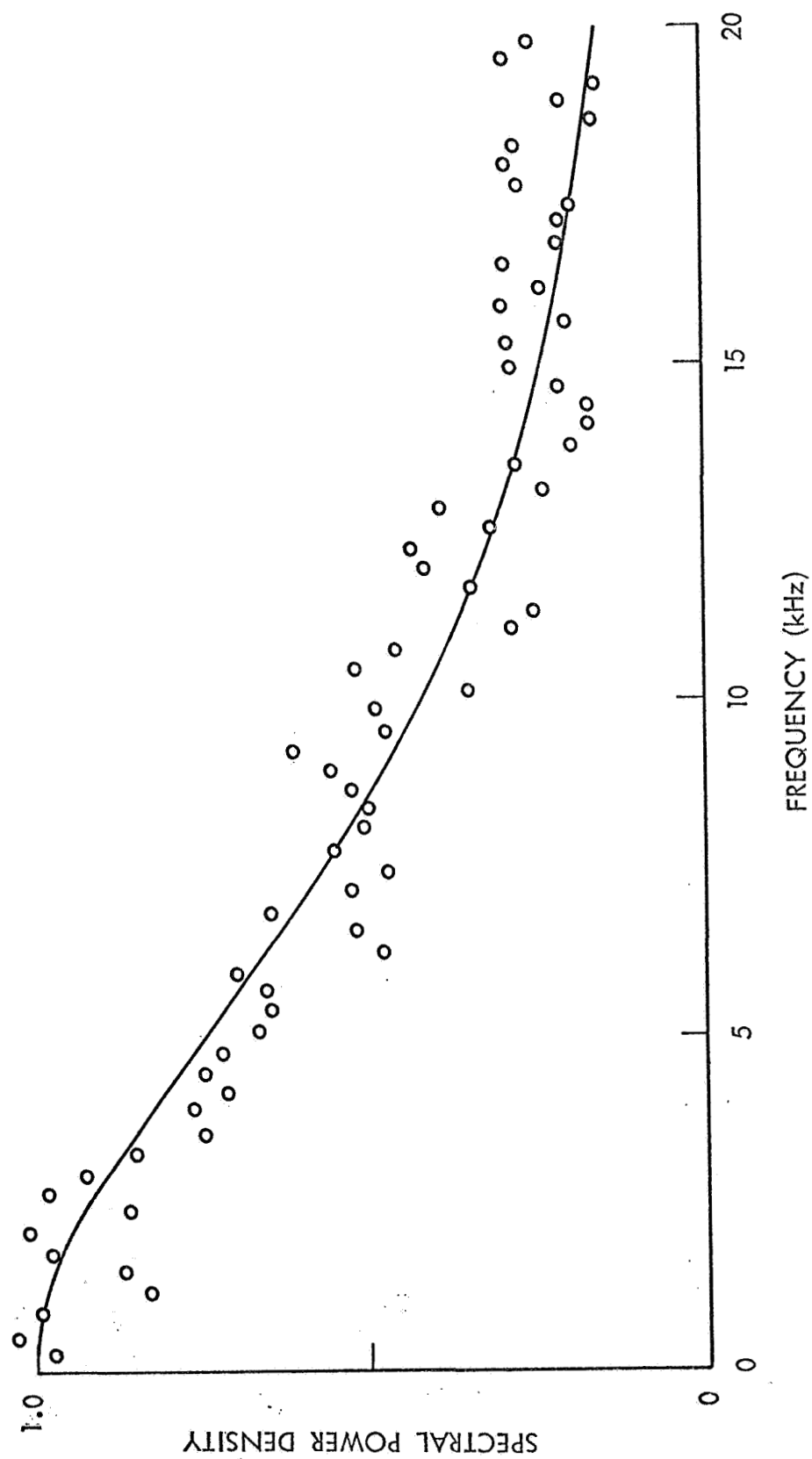


Fig. 2. Spectrum of light scattered from spheres of 910 \AA diameter suspended in a turbulent water jet. Scattering volume is on the axis, 40 nozzle diameters downstream from the nozzle. Flow rate: 20 ml/min. Solid curve is Lorentzian with 8.48 kHz width.



this fashion the spreading of the jet with increasing distance from the nozzle.

Further analysis is being undertaken in the hope that information about the kinetics of turbulent diffusion may be obtained in this manner.

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